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DESCRIPTION

• OF

THE IRON BRIDGE

OVER THE

MISSISSIPPI RIVER,

At HANNIBAL, Mo.

BUILT IN 1871,

BY THE

Detroit Bridge and Iron Works,

OF

DETROIT, MICH.

THE HANNIBAL BRIDGE.

From "The Railroad Gazette," July 15, 1871.

THIS combined railroad and highway bridge over the Mississippi River, at Hannibal, Mo., has just been completed, the seventh structure that spans the great river, below Dubuque. The work has been completed under the administration of the "Hannibal Bridge Company," formed by the consolidation of two companies—the "Pike County Bridge Company," incorporated in Illinois in March, 1867, and organized June 4, 1869, with Alexander Starne, President, and Ozias M. Hatch, Secretary and Treasurer; and the "Hannibal Bridge Company"—incorporated in Missouri, May 24, 1869. In December, 1869, the consolidation was effected under the present title of the company; Mr. John T. K. Hayward, of Hannibal, was elected President, and Ozias M. Hatch, of Springfield, Ill., Secretary. The present organization of the company is: Alexander M. White, President; Isaac M. Knox, Secretary and Treasurer; Warren Colburn, Consulting Engineer; Col. E. D. Mason, Chief Engineer, with E. L. Corthell and Eliot Clarke as assistants.

On the 27th of June, 1870, Col. Mason, with his corps, commenced the preliminary surveys, making minute examinations of the river bed and the underlying strata at various possible crossing places. By means of sounding rods, he bored to a depth at some points of 110 ft. below low-water mark. The direction and velocity of the cur-

rent was carefully noted by the use of floats, and the line of the bridge was located at right angles to it. A baseline of 1,620 ft. was accurately measured, and its extremities indicated by raised monuments. From this line as a base all the positions for the piers were located by triangulation, and afterwards tested by actual measurement with a steel wire, proving their accuracy.

On the 29th of July, 1870, a contract for both substructure and superstructure of the bridge proper, between and including the abutments on each side of the river, was entered into with the Detroit Bridge and Iron Works. The plans for the substructure had been previously prepared by Col. Ed. D. Mason, the Chief Engineer. The Bridge Company adopted the plans of superstructure as designed by Willard S. Pope, Engineer of the Detroit Bridge and Iron Works. The agreed price for the whole was \$485,000. By the terms of the contract the work was to be completed ready for use within one year. The time was very short—much less than that before given for any similar work, but the contractors have met the requirement.

This bridge belongs to the general class of "low bridges," placed but a short distance above the high-water mark, and furnished with a draw span over the channel to permit the passage of steamers and river craft generally. The comparative advantage of high and low bridges over navigable streams is a question of money only. The high bridge, offering practically no obstruction to river traffic at any stage of the water, and requiring no attention on the part of its keepers, in distinction from the constant service required at a draw, presents, in this respect, points of superiority over the low bridge. But the increased height of the piers, and the length of approaches neces-

sary to attain the elevation, adding very largely to the cost of the structure, led in this case to the adoption of the low bridge and draw as the most economical structure. Confirmations of this opinion are furnished by the bridges at Quincy, Burlington and Kansas City, as well as by the plan adopted for the bridge to be built at St. Joseph. At St. Charles, St. Louis, and Leavenworth high bridges have been favored and adopted for reasons other than those of economy.

The bridge under consideration is nearly identical in form with those at Burlington and Quincy, (built by the same contractors,) differing only in some of the mechanical details. One of the more important distinctive features is the form of the struts or posts used. These are composed of two parallel channel or I beams secured a short distance apart by diagonal bracing of wrought iron straps, forming an open-work strut, the interior of which is accessible to the brush of the painter, whose attention is frequently needed to prevent rust—the destroying enemy of iron structures. The free ventilation afforded prevents the condensation of moisture in the interior, and consequent rust, a salient feature of the tube-like "Phoenix column." In weight for the same strength there is little difference, while the facility of construction is slightly in favor of the new form. The form of the chord link differs from that used at Quincy in being formed of bars and eyes, instead of the experimental form built there of elongated links drawn out from a flattened ring. The upper chord shows an important modification. Instead of being of continuous size throughout, the ends of each section are considerably enlarged, and the abutting faces planed exactly perpendicular to the axes of the beams, thus adding

much to their stiffness, and allowing the omission of the short diagonal lateral braces. The increased size of the chord at the joints permits the passage of the tie rod to an interior fastening, instead of being secured to a *lug* on the outside.

The foundations, upon which depends the permanency of the work, in all cases—excepting that of the west abutment, which is built up from the rock—are supported upon pile bases. The piles in piers 2 and 3 were driven to the rock, and at the other piers they were driven until a sufficient resistance was obtained. Upon the piles, cut off at a level with the bottom, was placed a grillage of heavy timber, forming the foundation for a floating caisson. This caisson was sunk to its position as the masonry part of the pier was added to its weight, the sides being kept above water until the mass was fairly settled upon the pile heads. This method, when admissible, furnishes the most economical, as well as expeditious, means of placing the masonry upon foundations under water. To prevent scour, the spaces between the piles themselves, and the space between the bottom of the grillage and river bed, are filled up with riprap, and a bank is formed, around the outside, of the same useful material. The serviceable nature of riprap in resisting scour is well known, and the engineer in charge of this work has been led by his experience to place great confidence in its ability to withstand the currents of the Mississippi.

At the west abutment the rock bed of the river was found but a short distance below the surface, and the masonry was placed directly upon it. The rock, a variety of blue soapstone, was excavated in steps, to

receive the wing walls. This abutment contains 372 yards of masonry.

The following table shows the time occupied in the construction of each pier, and the depth of water at the several points at the time of the sinking of the respective piers:

PIERS.	Work Commenced.	Completed.	Depth of Water.
Pier No. 1 (west abutment).	Oct. 10, 1870.	May 27, 1871.	Ft. 0
" No. 2.....	Oct. 10, 1870.	Nov. 13, 1870.	18
" No. 3 (pivot pier).....	Dec. 10, 1870.	May 27, 1871.	31
" No. 4.....	Dec. 13, 1870.	March 8, 1871.	22½
" No. 5.....	Jan. 8, 1871.	Feb. 4, 1871.	14
" No. 6.....	Dec. 6, 1870.	March 5, 1871.	10
" No. 7.....	Nov. 22, 1870.	Jan. 31, 1871.	10
" No. 8.....	Jan. 27, 1871.	April 5, 1871.	12
" No. 9 (east abutment)..	Feb. 15, 1871.	April 22, 1871.	5

Pier No. 2, being situated in the current of the river, required protection piles as a guard against drift. All piles were driven to the rock bed, thus demonstrating that piles could be used for the sub-foundations, by properly protecting them from scour, with riprap placed between and around them by divers. The average number of blows to the piles in the foundations was 112, from a hammer weighing 2,700 lbs., falling 25 ft. at the last blow. A floating caisson, formed of a grillage of 12-in. sq. oak and elm timbers, well bolted together, and carrying planked sides to above the water line, was guided in its descent by cables, which were secured to a water-deadener, and side anchors, until it was settled upon the heads of the cut piles, at a depth of 18 ft. below the water line

of that date. The stonework consists of 496 cubic yards of masonry.

The piles of pier No. 3, the pivot pier, were driven to the rock, and, after dredging out the sand to a sufficient depth, were protected by riprapping. A sunken crib was used as a water-deadener. Much trouble was experienced from sand banks forming over the heads of the cut piles, requiring the use of divers, dredges, and, finally, a water jet thrown from a steam fire-engine.

The dipping of the rock bed carried it beyond the reach of the piles for piers 4, 5, 6, 7, 8 and 9, and these piles were driven in the sand until a sufficient amount of resistance was obtained; the permanency of the sand being secured by that indispensable material, riprap.

At piers 8 and 9 the sand had to be dredged out to allow the wooden grillage to be placed at a sufficient depth below low-water mark—the condition of durability of the wood-work being that it must *always* be covered by water, in order to exclude the air. In this situation it is practically indestructible.

The draw rests are sunk on islands of riprap, and consist of strongly braced cribs presenting a sloping edge to the current. Their interior is filled with riprap to the top.

The bridge is approached from the west by a long curve, completing a right angle with the river and passing through a tunnel of 302 feet in length, cut through what is called lithographic limestone. The excavation was made at the east heading, with Burleigh drills and powder and nitro-glycerine blasts. At the west end, by handwork alone, a heading of full width,

and some 9 feet in depth, was driven through the top of the heading, being on a line with the roof of the tunnel ; the bottom was cut out afterwards. The dimensions, after being lined throughout with brick, are 302 ft long, 20 ft. high, and 18 ft. wide.

Both entrances are ornamented with handsome cut-stone faces.

The approach at the east bank of the river is over $1\frac{3}{4}$ miles of embankment, across the river bottom land, broken at proper intervals, by paved culverts and roadways, and protected by revetment walls at points subject to wash.

The following analysis has been made of the two qualities of limestone from the Hannibal quarries used in the foundations.

The figures in this analysis give evidence of the comparative superiority of this limestone, as claimed by the engineer, in that it has comparatively small quantities of alumina, a small capacity of absorption and consequent density, and very great specific gravity.

CONSTITUENT PARTS.	Hannibal Brown Limestone, upper layer.	Hannibal White or blue Limestone lower layer.
Insoluble in acids.....	1.295	0.390
Iron	0.640	0.453
Alumina.....	0.550	0.852
Carbonate of Lime.....	80.805	93.365
Carbonate of Magnesia.....	14.650	2.320
Alkalies.....	1.060	1.120
Water	1.000	0.500
Total	100.000	99.500
Specific gravity.....	2.563	2.585
Weight per cubic feet.....	159.74	161.00

As stone from the same quarry has already stood long and severe tests in some of the older buildings at Hannibal, there is no necessity for fine argument upon its chemical composition, and no reasonable doubt can be entertained of its being all that is required for the purpose.

In the foundations there were used 650,000 ft. (board measure) of square timber and plank, 709 piles, and 6,270 cubic yards of riprap. There are 4,519 cubic yards of masonry in the piers, distributed as follows, numbering the piers from the west bank: No. 1, 372; No. 2, 426; No. 3, 1,340; No. 4, 514; No. 5, 400; No. 6, 326; No. 7, 333; No. 8, 310; No. 9, 430.

In the superstructure are 1,000 tons iron, and 280,000 ft., board measure, of timber and planks in flooring.

The cost of the bridge proper was \$485,000, the tunnel on the west bank, \$36,000; the west approach, \$56,000, and the east approach, \$71,500—making the total cost of the structure \$648,500

SUPERSTRUCTURE.

The spans are arranged as follows: Beginning at the west bank of the river, one fixed span, 250 ft. long; one pivot draw-span, 162 ft. long, leaving, when opened, a passage way for steamboats 160 ft. clear width on each side of the draw pier; one fixed span, 250 ft. long, and four fixed spans 180 ft. long each. The measurements of length are taken in each case, from centre to centre of bridge-seats of abutments. The total length of iron superstructure is 1,582 ft.

The superstructure is of the general style known as the quadrangular truss, with horizontal and parallel chords, vertical struts—except those at the ends, which are inclined over one panel,—and inclined ties. In the fixed spans the upper chords and the joint pieces, etc., are of cast iron, and all the remaining parts are of wrought iron. The draw span is of wrought iron throughout, except joint pieces and wheels, track, etc., of the turn-table; the flooring is placed at the bottom of the bridge, and is uniformly 18 ft. wide.

The general characteristics of the different lengths of spans are as follows:

	In draw span 362 feet long.	In one fixed span 250 feet long.	In one fixed span 180 ft. long.
Depth of truss between { at pivot pier centre of chords, { at ends.....	34 feet. 26 "	25 ft.	23 feet.
Width between centre of chords.....	20 "	19.6 ft.	19.6 feet.
Number and length { 2 centre panels. of panels, { 26 ordinary pan'l	11.2 " 12.11 ft.	19 pan 13 ft.	13 pan 13.7 ft.
Weight of cast iron.....	65 tons.	50 tons.	25 tons.
Weight of wrought iron.....	235 "	125 "	63 tons.
Oak flooring.....	31 M.	22 M.	16 M.
Pine flooring.....	31 M.	22 M.	16 M.

STRENGTH OF BRIDGE.

The main parts of the structure are so proportioned that a moving or live load of 2,500 lbs. per lineal ft. of bridge, in addition to the weight of the structure itself, and the flooring thereon (or the dead load), shall bring

on no part a greater strain than one-fifth of its ultimate capacity. This general rule was applied to those parts which receive their assumed load only when the whole or a considerable part of the span may be occupied by a train of the assumed maximum weight. Those parts, such as single-panel systems, which receive their full load each time an engine may cross the bridge, are utilized to the extent of only one-sixth their ultimate capacity, while the bolts supporting the floor system can never receive a load exceeding one-eighth their strength. The actual relation, therefore, between the calculated final strength of the structure and its assumed working duty is shown to be as follows, taking the 250-ft. span as an instance:

Dead weight of span,.....	240 tons.
Live load of span,.....	310 "
Total weight and load, ...	550 "
Ultimate strength of bridge (factor of safety 5),.....	2,750 "

The dead weight, of course, remains constant under all conditions; therefore, of the gross strength of the bridge, 2,510 tons is applicable to the support of the live load, which is in the ratio of more than 8 to 1.

In other words, when the bridge is fully loaded with its assumed maximum of 2,500 lbs. per lineal ft., it will still be capable of sustaining before fracture the imposition of an additional load of 2,200 tons.

This large excess of strength is practically still further increased, from the fact that the assumed live load of 2,500 lbs. per lineal ft. can never be actually reached, even though the bridge were loaded from end to end with engines, and from the additional fact that the actual strength of the iron used is considerably in excess of that demanded by the specifications. This combination of

circumstances and facts gives a reasonable assurance of abundant strength.

CONSTRUCTION.

The top chords of the fixed spans are of cast iron, octagonal in exterior section and circular within. In the 250 ft. spans these chord pieces are 14 inches in diameter between the opposite exterior faces. The thickness of metal varies with the varying strains.

They are cast in lengths of one panel, the joint occurring immediately over the head of the vertical posts to which each chord-piece is bolted. The ends are widened for the reception of the post-head, the main and counter tie-rods, and the upper lateral strut and ties, all of which assemble at that point. Thus while in the 250 ft. spans the chord-pieces are 14 in. wide throughout their interior length, they widen at their ends to 24 in. This increase of width at the joints increases largely the lateral stiffness of the bridge. Where the chord-pieces abut against each other, their faces are turned off in a lathe square and true to their axes, and they are connected with each other by a tenon and socket joint.

Immediately under the joint is placed the post or vertical strut, the seat for which, on the under side of the chord, is planed to a true bearing. The post-head is of cast iron, machine-finished to correspond with its seat. The posts themselves are of rolled channel or I beams, arranged in pairs, connected together by a system of wrought-iron riveted lattice-work. The two beams thus united form a hollow, open post, rectangular in section.

They range from 10 in. to 24 in. wide, varying in depth with the depth of the constituent beams. The beams extend from the post-head to a point 6 in. below the centre of the main coupling-pin, passing through their foot; the pin-seat in the post being reinforced by a cast iron plate or washer riveted to the web of the beams. The beams of which the posts are built vary in dimensions in accordance with their duty, from channel beams of 6 in. depth, weighing 10 lbs. per ft., to I beams of 15 in. depth, weighing $66\frac{2}{3}$ lbs. per ft.

It will be seen from this description that the posts are continuous and without transverse joint from end to end; and, furthermore, that all faces or sides of the iron of which they are built are at all times open to inspection and accessible to the paint-brush. It is considered that this is a material improvement over the closed cylindrical wrought-iron posts that are often used in similar places. Such a construction generally involves the necessity of an independent cast-iron foot or base, thus placing a full transverse joint across the body of the post; and, furthermore, the inside of these posts can never be reached either for inspection or protection, after they are once in place.

The main and counter ties are placed in pairs connected at the lower end with the bottom chords and posts by a pin, and at the upper end passing through the top chord immediately over the post-head and secured in their position by nut and screw. They run diagonally, reaching from the pin at the foot of one post to the head of the second post beyond, their vertical rise being the depth of the truss, and their horizontal reach being the length of two panels. They are of rolled iron, square in section, their lower part being formed into a loop,

which is drilled to fit the pin; and their upper end being shaped into a cylindrical form on which the screw is cut. The end forming the screw is enlarged so that the sectional area of metal at the bottom of the screw thread is in each case larger than the sectional area of any part of the body of the bar. The nuts are faced to a true and perfect bearing on their respective seats.

The lower chords are of square iron of the length of one panel, formed with a drilled loop at each end, through which the pins pass. They vary in size and number in each panel, according to the duty demanded by their position. In their manufacture the most scrupulous care was taken to have them all of exactly uniform length between centres of pin-bearings.

The upper lateral struts are of rolled channel beams 6 in. deep, weighing 10 lbs. per ft., placed in pairs, between the top chords at their joints over the post-heads. The lateral ties above and below are of round iron bars $1\frac{1}{4}$ in. in diameter.

The floor-beams consist of rolled I beams 15 in. deep, weighing 50 lbs per ft., suspended in pairs from the pins at foot of posts. The bolts suspending the floor-beams and the coupling-pins are forged bodily from selected scrap, under heavy hammers, and afterwards machine-finished for their respective positions.

The above description of the parts of the fixed spans applies equally to the draw-span, except that in that span the chords are necessarily different, as is demanded by the varying nature of the strains, which change from compressive to tensile, or the reverse, as the draw is open or shut.

They are built of channel beams 12 in. deep, $33\frac{1}{2}$ lbs. per ft., placed in pairs, and connected together with plate

iron, thus making generally a trough or hollow box of three sides, 24 in. wide, and about 12 in. deep. The joints, which are carefully broken, are spliced with appropriate cover-plates, and the whole thoroughly riveted together.

The top and bottom chords are substantially similar, varying in dimensions, etc., only with the varying duty.

The turn-table on which the draw-span revolves consists of a rectangular hollow girder or drum, 18 in. wide, and $4\frac{1}{2}$ ft. deep, curved to a circle, with an exterior diameter, of $31\frac{1}{2}$ ft. The sides of this drum are of plate iron, and the top and bottom are of cast iron, and are separated by 30 cast-iron stiffeners, or diaphragms, carefully fitted to which, and to the top and bottom segments, the side plates are thoroughly riveted. The circular drum revolves upon 48 heavy cast-iron wheels or rollers, placed under it, and they in their turn rest upon a cast-iron track bolted to the masonry of the pier. These wheels are connected with each other and with the centre step by bands and radial axles. The wheels and the upper and lower track bearings are chilled to great hardness to resist wear. From the bottom of the revolving drum pass truss-rods, the upper ends of which bear upon a heavy central cast washer, at the bottom of which is the pivot-pin, of wrought iron, 8 in. in diameter. This pivot-pin turns upon a gun-metal bearing in the top of a central conical block of cast iron, which is fastened to the masonry.

The adjustment of the load between the exterior wheels and the central pivot is made by means of the truss-rods above mentioned.

The ends of the draw are secured in their position on the piers by means of a system of cams, so arranged

with screw and connecting rods as, when being run down, to absolutely lift the ends of the bridge. This device is essential, as otherwise, when a train might be entering upon one end of the draw, one wing being thus loaded and the other wing being empty, the unloaded end would rise from its bearings, and thus serious and complex strains be induced upon parts of the structure.

But by absolutely and sufficiently lifting the ends of the bridge upon solid bearings this difficulty is entirely avoided, and the structure can thus be treated legitimately and correctly as a beam resting upon three points of support, and the complexity of the problem of strains be immensely simplified.

The bridge is turned and the machinery of the end cams operated by a double engine of about twenty-horse power (nominal) placed on an iron platform laid for the purpose on beams supported by the main posts over the turn-table. This platform or floor is placed at a sufficient height above the lower chords to allow the passage of trains beneath it.

QUALITY OF MATERIALS.

Samples of all the wrought-iron bars used in the bridge were tested to their ultimate capacity before acceptance.

The tensile strength ranged from 55,000 to 65,000 lbs. per sq. in. of sectional area, and the lowest limit of permanent set was about 25,000 lbs. per sq. in.

The stretch before final rupture was about 20 per cent. of the length of the original bar, and the diminution of area proportional therewith.

The cast iron was from a mixture of 75 per cent. of No. 1 Lake Superior charcoal pig, with 25 per cent. of Scotch pig of the brand known as "Calder iron."

Test pieces were cast 2 in. deep, 1 in. wide, and 40 in. long. These were placed edgewise upon bearings 36 in. apart, and were called upon to sustain the traverse strain from a load of 2,800 lbs. placed at the centre. All the test pieces showed higher capacity.

The hollow chord pieces were drilled and accurately callipered for thickness.

After manufacture and before being placed in the bridge, each piece of bar iron was placed in the testing machine, and subjected to an actual tensile strain of 15,000 lbs. per sq. in. of sectional area, and while under such actual strain, received several sharp blows from a hammer. Any imperfection or weakness detected by this treatment condemned the bar. Of the many hundreds of bars thus treated, only two exhibited any sign of failure, and in both these instances the defect was in the original bar, and not in any part that had been worked at the shops. As soon as finished, and before leaving the works, every piece received one coat of paint, composed of oxide of iron and oil.

All the iron work was done at the shops of the Detroit Bridge and Iron Works, at Detroit, and having been fitted together there, each piece was marked, so that when brought to the place of final erection every part went to its place with perfect accuracy.

FLOORING

Upon the iron floor-beams are laid pine stringers, placed longitudinally. Under each rail in the track are

two pieces, 7x16 in., and addition thereto are four parallel pieces, 6x14 in. All these are laid upon small oak bolsters, which rest upon the iron beams. On the top of the stringers are oak ties, 6x8 in., spaced about 20 in. apart, between centres, reaching entirely across the bridge. A double course of 2-in. oak flooring-plank forms the roadway, the track for engines and cars being of the pattern known as street rail, the top of which is flush with the top of the oak flooring. A substantial oak wheel-guard, and a strong, neat hand-rail form the side protection.

PAINTING.

The entire superstructure received, after erection, two thorough coats of paint. For the main trusses the paint was of strictly pure white lead, tinted to a light drab, while the floor-beams and track-stringers were covered with iron paint of a dark brown shade.

NOTE.—The first train crossed the bridge, August 1st, 1871. By reason however of the incomplete state of the tunnel and approaches, the structure was not opened for regular traffic until September, 1871.

WM. C. COLBURN,
Secretary and Treasurer.

Detroit Bridge and Iron Works.

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The Iron Bridge over the Mississippi, Hannibal, Mo.

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ADDRESS

DETROIT BRIDGE & IRON WORKS.

DETROIT, MICH.